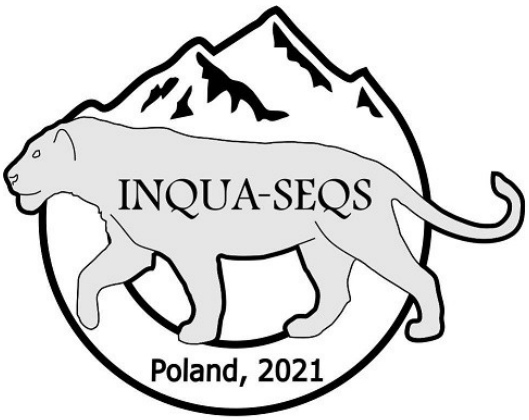

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LONG TERM PANNONIAN FLUVIAL MAGNETIC SUSCEPTIBILITY RECORDS DOCUMENTING ALPINE PERMAFROST DEVELOPMENT IN COLD EVENTS OF THE EUROPEAN QUATERNARY

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In 2015 (at Strati2015, Graz, Austria) the magnetic susceptibility (MS) was invoked as a possible correlation tool in Quaternary alluvial stratigraphy. The reason of this idea was that, according to the mineralogical investigations, the high MS values observed regularly in the 440–480 m thick fluvial sediment sequence of the Körös Basin (East Hungary) are determined by the climatic control on delivery and preservation of magnetic minerals, mainly of magnetite (Püspöki et al. 2016 figure 6). The possible explanation was that under cold-and-dry climate these minerals were released owing to frost shattering in the adjacent hinterlands and were transported to alluvial plains in the early postglacial periods thanks to the increasing discharge of rivers. However, with further warming the weathering-sensitive magnetic minerals soon disappeared from the soils of the catchment area and thus from the fluvial load (figure 11 *ibid*).

Between 2016 and 2019 further studies on 350–650 m thick Quaternary fluvial successions in the adjacent sub-basins (Jászság Basin, Makó Trough) were performed to extend the initial observations. The cross-basin correlations were based on the laboratory measurements of MS values (0.5–1 m sample steps) in fully cored boreholes, and on complementary palaeontological (molluscan) data. The resulted age models were confirmed by multi-proxy time series analyses revealing fundamental Milankovitch frequencies (~100 and ~41 ka) in the correlated sections. These investigations indicated that (1) the climate-dependent fluvial MS signal can be traced far into the basin in both channel and floodplain environments and (2) can occur related to various sources of magnetite in the catchment areas. The early postglacial escape and spreading of the magnetite fraction can greatly support (1) the mapping of the unconformable Quaternary base, (2) the cross-basin correlations between different sub-basins (Püspöki et al. 2020 figure 4) and (3) the cross-facies correlation in the heterogeneous alluvial sequences (supplementary figure 1 at the same place), in short, (4) high-resolution Quaternary stratigraphic correlations and reservoir modelling in the Pannonain freshwater aquifer system. With the Alps in the catchment area, it was also recognised that in the case of significant altitudes in the associated catchment area, orographic aspects can also occur in the climatically controlled fluvial MS record, as the gradually retreating permafrost zone causes upwards decreasing trends in the MS records (Püspöki et al. 2021a, figure 11).

Based on these preliminaries, in 2021 the high-resolution regional Quaternary stratigraphy of the Great Hungarian Plain was established by correlating the fluvial MS records of 13 fully cored boreholes eight of which represent complete or almost complete Quaternary (2500 ka) sections (Püspöki et al. 2021b, figures 4 and 5). Additionally, supported by the evaluated palaeomagnetic reversals and instability events in the most representative Dévaványa and Vésztő borehole sections, the regionally correlated MS peaks were correlated to the cold stages of the marine isotope stage records (MIS) (Lisiecki and Raymo 2005). The regionally relevant MS peaks represent MIS 104, 100, 98, 82, 60, 52, 34(-36) and 26 of increased heavy oxygen isotope value, constituting the significant Early Pleistocene glaciations, and MIS 18, 16, 12, 8, 6 and 2 (figure 6 *ibid*) mostly representing the substantial Middle and Upper Pleistocene European glaciation events (Ehlers and Gibbard 2004). Thus, the interpretation of early postglacial fluvial MS maxima was confirmed by the correlation of MS peaks to the changes of the global ice volume. As a result, fluvial MS records can be considered as a proxy on mountain permafrost development in the catchment areas.

The correlation to the sea-floor stratigraphy confirmed that the main Pannonian Quaternary sub-basins are sites of almost continuous fluvial/alluvial records of the past 2500 or even 2600 ka. Thus, the Pannonian Quaternary fluvial succession is sufficiently complete to provide satisfactory records of mountain permafrost development of the Alp-Carpathian region the latter being a globally relevant European representative of the mid-latitude mountain regions.

The similarity of the Pannonian fluvial MS records as a potential permafrost proxy, for example to the marine ice-rafted detritus (IRD) records (Mangerud et al. 1996, Jansen et al. 2000) and MS data of Chinese loess/palaeosol sequences (Ding et al. 2005, Sun et al. 2006), promises further comparative investigations and joint interpretations of the globally relevant proxy records and the mid-latitude mountain permafrost development (Püspöki et al. 2021b, figure 9). To support these comparisons, the palaeomagnetically documented Dévaványa borehole section can be proposed as a potential reference section of the European intra-terrestrial Quaternary fluvial deposits.

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